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ELECTRONIC PROCESSES IN InP AND RELATED COMPOUNDS.

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K.V. Vaidyanathan, C.L. Anderson, H.L. Dunlap, D.E. Holmes and G.S. Kamath

Hughes Research Laboratories

3011 Malibu Canyon Road

Malibu, CA 90265

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Liquid phase epitaxy of InP
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An experimental system to measure ionization coefficients in InP and related compounds is described. The growth of high purity liquid phase epitaxial InP is described and the properties of such layers discussed.

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1. INTRODUCTION AND SUMMARY

The major purpose of this research program is to study the electronic processes in InP and related compounds, to develop device structures suitable for making photocurrent measurements, and to analyze the bias dependence of the photocurrent to obtain the ionization coefficients of electrons and holes in these materials. Such measurements will be useful in the optimal design of avalanche photodiodes for optical communications systems.

During this reporting period, primary emphasis was placed on two areas. The first was to assemble experimental equipment for photo-response measurements and the analysis of the photoresponse data. The second was doping level and morphology control in the liquid phase epitaxial growth of InP.

The calculator-based experimental system has been assembled and is described in detail. We have successfully grown high purity epitaxial layers with excellent morphology. We are presently investigating the growth of silicon doped n^+ epitaxial layers.

2. IONIZATION COEFFICIENT MEASUREMENTS

The noise and gain-bandwidth product limitations of avalanche photodiodes are strongly dependent on the ionization coefficients of electrons (α) and holes (β) in the material. These coefficients are obtained from a study of photocurrents. To obtain this information, it is necessary to achieve photomultiplied currents from pure electron and pure hole injection into the high field region of the device structure. In addition, the electric field variation in the avalanche region must be known accurately.

In our experimental system, we hope to accomplish the pure electron and pure hole injection by the absorption of either 0.638 μm or 1.152 μm radiation. Two stable He-Ne lasers, one capable of operation at 0.638 μm and the other at 1.152 μm provide the necessary illumination. Chopped light from the two lasers is focused onto optical fibers, labeled 1 and 2 in Figure 1. The two fibers are fused together in the middle, allowing
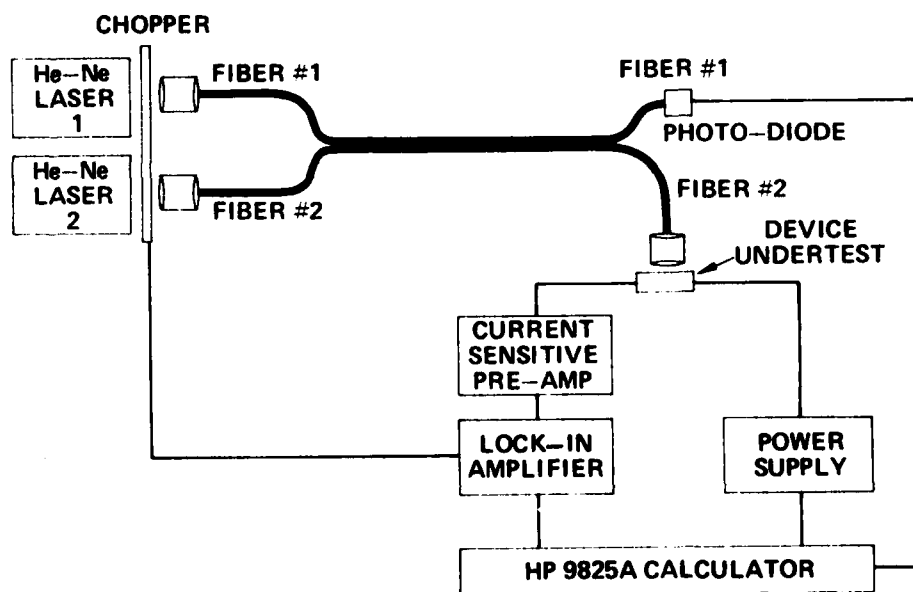
Figure 1. Schematic diagram of ionization coefficient measurement system.

coupling of radiation between the fibers. Approximately 50% of the
radiation couples from fiber 1 to fiber 2 and vice versa. Radiation
from fiber 1 is focused by a microscope objective onto the device struc-
ture, as shown in Figure 1. The radiation from fiber 2 is detected by
a reference photodetector and provides a measure of the laser intensity
incident on the test device at any given time. This feature will allow
us to account for any fluctuations in the laser intensity during the
time it takes to complete the measurement. The photo-induced currents
will be measured by a current-sensitive preamplifier and a lock-in
amplifier. The voltage applied to the device under test and the measure-
ments will be controlled by a HP 9825A calculator. The system has been
assembled and the interface between the calculator and the lock-in
amplifier is being designed. The entire system will be available for
measurements in early next quarter.

3. LIQUID PHASE EPITAXY OF InP

We have continued the growth of high purity InP epitaxial layers
and have concentrated our efforts on achieving control over surface
morphology. The high oxidation rate of InP at room temperature and the
tendency toward thermal degradation of the material at the growth tem-
perature make it necessary to carefully clean and prepare the substrate
prior to growth. We have observed that by chemical/mechanical polishing
the substrate in cold bromine-isopropyl alcohol, followed by an
isopropyl alcohol quench, acceptable surfaces can be prepared. The
epitaxial layers grown on such substrates exhibit acceptably smooth
surfaces.

During the growth experiments, we have observed that by adding
small quantities ($\sim$1 to 10 ppm) of water vapor to the growth ambient,
the carrier concentration in the grown layers can be reduced to
$\sim$2 x 10^{15} cm^{-3}. Layers with reproducible electrical properties can be
grown under these conditions. Typical layers exhibit room temperature
mobilities of $\sim$4500 cm^2 V^{-1} s^{-1} and liquid nitrogen mobilities as high
as $\sim$40,000 cm^2 V^{-1} s^{-1}. Low temperature photoluminescence analysis of
the high purity samples show a narrow bandedge emission at $\sim$1.42 eV and

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absence of any donor-acceptor emission at $\sim$1.38 eV. The 1.38 eV emission band has been observed in samples which have carrier concentrations of $\sim$8 x 10^{16} cm^{-3} grown from the same melt without water vapor addition.

During this quarter we have performed preliminary secondary ion mass spectrometry (SIMS) and Auger electron spectroscopy (AES) analyses of epitaxial layers grown with and without water vapor in the growth ambient. The data show that layers grown in the absence of water vapor exhibit considerable amounts of silicon in the grown layer ($\sim$1 x 10^{17} cm^{03}). However, the samples grown in the presence of water vapor exhibit much lower silicon concentration ($\sim$2 x 10^{16} cm^{-3}). The observations can be explained on the model that the quartz in the growth chamber is reduced by the hydrogen ambient, resulting in silicon doping of the solution. In the presence of small amounts of water vapor, the reduction of quartz is suppressed, thus resulting in a purer solution.

During this quarter, we have also investigated the growth of heavily doped InP layers. Several layers with donor concentration of $\sim$1 x 10^{18} cm^{-3} have been grown with excellent morphological control.

4. PLANS FOR THE NEXT QUARTER

During the next quarter, we will investigate the growth of high purity layers and the growth of lightly doped p-type layers by adding Be to the solution. The interface between the lock-in amplifier and the HP9825A calculator will be completed early next quarter. Preliminary photoresponse measurements will be carried out on Schottky barrier structures on lightly doped p-type bulk InP.

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Naval Air Systems Command
Washington, DC 20361
Attn: AIR-310B (Mr. James Willis)
            (5 copies)
        AIR-950D6 (14 copies)

Naval Ocean System Center
Code 922 (Attn: Mr. Harry Wieder,
                Dr. A. Clawson)
San Diego, CA 92152

RCA
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MIT
Lincoln Laboratory
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P.O. Box 73
Lexington, MA 02173

Office of Naval Research
Code 427 (Attn: Dr. John Dimmock)
800 N. Quincy Street
Arlington, VA 22217

U.S. Army Research Office
Attn: Dr. H. Wittmann
P.O. Box 12211
Research Triangle Park, NC 27709

Advisory Group on Electron Devices
Attn: Working Group "C"
201 Varick Street
New York, NY 10014

Dr. Roy Potter
444 S. State Street, Apt. #309
Bellingham, WA 98225

Varian Associates
Solid State Laboratory
Attn: Dr. George Antypas
611 Hansen Way
Palo Alto, CA 94303

The University of Michigan
Electron Physics Laboratory
Department of Electrical and
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Attn: Prof. Brenton L. Mattes

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